# FIRE ECOLOGY OF A MONTANE PINE FOREST, JUNIPERO SERRA PEAK, CALIFORNIA

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Abstract

Between 1640 and 1907 fires hot enough to produce basal scars on pines in a small isolated *Pinus lambertiana* forest in the Santa Lucia Range of central California occurred on the average of once every 21 years. Excepting two small lightning fires that were quickly extinguished, no fires occurred in the pine forest after 1907 until the lightning-caused Marble-Cone fire burned the entire forest in 1977. This was the most intense burn recorded within the life of the present forest. It caused significant loss of pines, particularly within the 40 percent of the forest on the north summit above 1600 m elevation. Changes in forest composition resulting from the Marble-Cone fire suggest that several more fires following 50–75 year intervals may eliminate *P. lambertiana* forest above 1600 m on Junipero Serra Peak.

Recurrent light fires are essential for development and maintenance of montane pine forest in the western United States (Cooper, 1960). Fires originally set by lightning and Indians removed dead and senescent trees, furnished a desirable seedbed, and thinned the subsequent regeneration. These periodic surface fires kept fuel levels so low that conflagrations were rare (Cooper, 1961). In California such low intensity fires have been documented for pine and mixed conifer forests of the Sierra Nevada (Wagener, 1961; Biswell, 1967; Kilgore and Taylor, 1979), north Coast Ranges (Biswell, 1963), Mt. Pinos region (Vogl and Miller, 1968), and San Bernardino Mts. (McBride and Laven, 1976). The role of fire in disjunct forests of the central California Coast Ranges has remained unstudied.

Junipero Serra Peak (J. S. Pk.) is the highest point (1788 m) in the Santa Lucia and adjacent ranges (Griffin, 1975a). Montane pine forest dominated by *Pinus lambertiana* covers 146 ha on the peak's north slope (Fig. 1). The J. S. Pk. and nearby Cone Peak forests are isolated from the next *P. lambertiana* stands by 220 km (Griffin and Critchfield, 1972). The J. S. Pk. pines are surrounded by a vast area of scrubby mixed hardwood forest and chaparral. We evaluate the fire history of the pine forest and examine the effect of past fires on forest composition. An analysis of forest plots before and after the severe Marble-Cone fire of 1977 is given.

Madroño, Vol. 27, No. 2, p. 49–60, 16 April 1980

## Local Fire History

The fires that scarred old *P. lambertiana* trees on J. S. Pk. span four land management eras: Indian (before 1800); Spanish and Mexican (1800–1847); American settlement (1848–1906); and U.S. Forest Service (since 1907). Through all four eras both lightning strikes and humans started fires on the peak or close enough to reach the peak during hazardous fire periods.

Three Indian groups held territory around J. S. Pk.: Esselens, Costanoans, and Salinans (Kroeber, 1925). The peak had religious significance to the Salinans, and the southwestern base of the mountain is rich in Salinan materials, including two prehistoric settlements (Lick Observatory, 1977). Nothing is known of Esselen fire habits, but widespread burning in grassland and oak woodland is documented for Costanoans and Salinans (Gordon, 1977). Reports of Indians burning chaparral or forest vegetation types in the interior of the Santa Lucia Range are lacking (Burcham, 1959); however, Indian burning in grassland or oak woodland could have spread long distances to the J. S. Pk. forest during the long dry seasons.

We also know few details about the local burning practices of the Spanish and Mexicans or even the first American ranchers who replaced them. There are conflicting views on whether they started more or fewer fires than the Indians. But in the 1890's government files and newspapers began to record specific large fires in the Santa Lucia mountains. An 1894 fire burned for weeks covering the upper watershed of every permanent stream in the central Santa Lucia mountains (Plummer and Gowsell, 1905). Many settlers started fires that were "allowed to run" so as to facilitate passage of their livestock. In July, 1903, an escaped campfire in the north-central Santa Lucia mountains burned for months, covering an area about 10 km wide extending 20 km to the coast (Sterling, 1904). Another fire in October, 1906, burned about 55,000 ha stretching 39 km across the northern Santa Lucia mountains (Los Angeles Herald, 1906). While these specific fires did not reach J. S. Pk., they show that the vegetation did carry some regional fires—even when deliberate and accidental fires were so frequent that surface fuels must have been well below current levels.

Primitive fire control in the Santa Lucia Range began in 1907 with the establishment of the Monterey National Forest (now the Monterey District, Los Padres National Forest). Within the National Forest the annual burn was about 3200 ha through the 1920's but declined to about 160 ha by the 1960's (U.S. Forest Service, undated). In 1970 this trend was dramatically reversed by the man-caused Buckeye fire, which burned 24,000 ha. In 1977 the 72,000 ha Marble-Cone fire was the second largest blaze in California records (Griffin, 1978).

Until 1977 the total area burned by lightning fires in the Santa Lucia mountains was modest. About 1000 ha burned after a rash of lightning

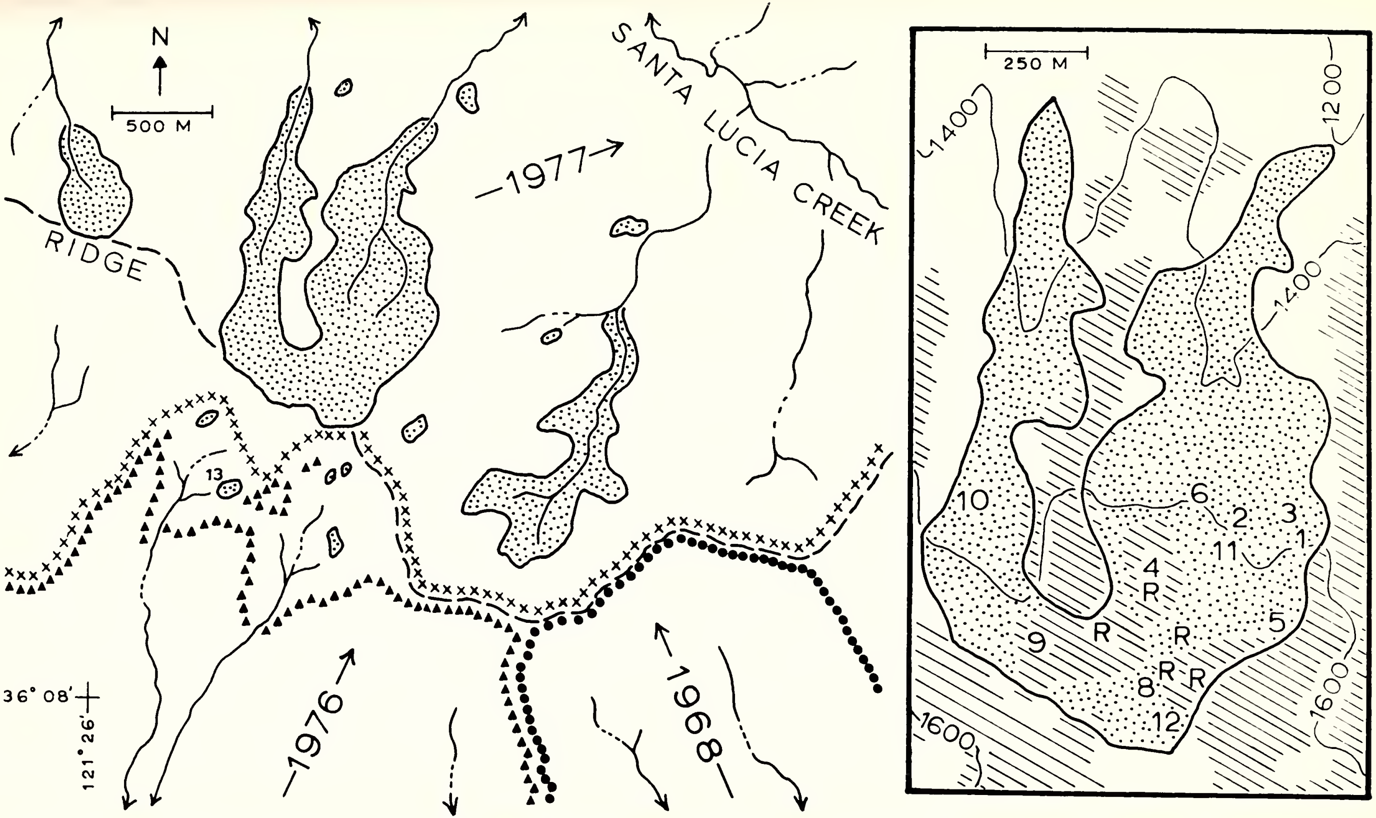


FIG. 1. Junipero Serra Peak region with distribution of *Pinus lambertiana* (stippled); edges of 1968 Rattlesnake fire (dots); 1976 Indians fire (triangles); 1977 Marble-Cone fire (×'s); and south slope outcrop plot 13. Insert shows enlargement of central pine population (stippled), 1976 stand plots (numerals), 1978 regeneration plots (R's), areas of tree and shrub canopy destroyed by crown fire (hatched), and 200-m contours.

strikes in August, 1916. Between 1931 and 1977 only 39 lightning fires were officially recorded on the Monterey District; a smaller number started on private lands adjacent to the National Forest. All these fires were extinguished while still small. If left uncontrolled, some of these could have become major fires and spread to J. S. Pk. On August 1, 1977, a lightning storm started eight fires. Four fires outside the National Forest were quickly suppressed, but four within the rugged Ventana Wilderness merged into the Marble-Cone conflagration.

Historical fires on the summit of J. S. Pk. start with a major blaze in 1901 that covered most of the mountain (Plummer and Gowsell, 1905). There are no other records until September, 1939, when lightning started a 0.4-ha fire in oak scrub on the northwest ridge. Lightning also started a 0.4-ha fire in pine forest on the north slope in September, 1959. A vehicle on Fort Hunter Liggett started the Rattlesnake fire in June, 1968. This 1300-ha fire burned up the south slope of the mountain through chaparral (Fig. 1). The man-caused 2800-ha Indians fire in May, 1976, burned up the southwestern slope of the peak through chaparral and scrubby mixed hardwood forest (Fig. 1). The Indians fire burned into the margin of the Rattlesnake burn. After burning for a week, the August, 1977, Marble-Cone fire reached J. S. Pk., skirting the Indians burn and then covering the entire north slope of the mountain (Fig. 1).

## Methods

We started mapping the J. S. Pk. pine forest on the 7.5 min Junipero Serra Peak topographic sheet in 1975 using black-and-white 1968 aerial photography and field observations. In 1976 thirteen sites representative of the pine forest diversity (Fig. 1) were analyzed using 0.07-ha plots (22.9 m × 30.5 m) with the long axis parallel to the slope direction. Shrub and herb strata were assessed using tabular comparison (Mueller-Dombois and Ellenberg, 1974). Tree species 5 cm dbh or greater were evaluated using count-plot methods for density, cover, and basal area. Heights of pines less than 5 cm were also measured. Fire dates were determined by aging fire scars on large *P. lambertiana* trees with methods similar to those of Arno and Sneck (1977).

All plots were reexamined in July, 1978, 11 months after burning. Plot 7 (not shown in Fig. 1) was unusable because of bulldozer damage during the fire, but the remaining plots were redone using 1976 methods. At this time the sampling of fire scars was increased. Patterns of fire intensity were mapped onto the same topographic sheet from color infrared aerial photography (taken 1 month after the fire) and field observations. We also established five 0.1-ha permanent plots for long-term pine regeneration studies. In 1978 and 1979, pine seedlings on each plot were counted, and shrub seedlings on plot subsamples were counted.

TABLE 1. ESTIMATED DATES OF FIRES SCARRING *Pinus lambertiana* TREES ON OR ADJACENT TO JUNIPERO SERRA PEAK STUDY PLOTS. Dates within a given row are believed to represent the same fire.

| Plot 3 (1 tree) | Plot 5 (2 trees) | Plot 6 (1 tree) | Plot 8 (3 trees) | Plot 10 (2 trees) | Plot 12 (2 trees) |
|---|---|---|---|---|---|
| 1977 | 1977 | 1977 | 1977 | 1977 | 1977 |
| | 1959 | | | | |
| 1901 | 1901 | 1901 | 1901 | 1901 | 1901 |
| | 1896 | | | | 1896 |
| | 1872 | 1872 | 1872 | 1872 | 1872 |
| | 1852 | 1853 | | 1852 | |
| | 1840 | 1842 | 1842 | 1845 | 1843 |
| | 1820 | 1826 | 1826 | 1826 | 1825 |
| | | | | | 1812 |
| | | 1809 | | | |
| | | 1801 | | | |
| 1793 | 1791 | 1795 | 1795 | 1795 | |
| | 1786 | | | | |
| | 1758 | 1757 | | 1759 | |
| | | | | 1755 | |
| 1743 | 1746 | | | | |
| | 1740 | 1734 | | 1739 | |
| | 1724 | 1717 | | 1722 | |
| | | 1707 | | | |
| | | 1700 | | | |
| | 1688 | 1683 | | | |
| | | 1668 | | 1671 | |
| | | 1664 | | | |
| | | 1651 | | | |
| | | 1640 | | | |

## RESULTS AND DISCUSSION

*Fire scar analysis.* Intervals between fire scars on individual plots ranged from 4 to 108 years (Table 1). Eleven of the fires involved were spot fires or else not hot enough to scar trees on several plots (Table 1). Over the entire time period the average interval between scars on a given plot ranged from 19 to 78 years. Prior to fire control in 1907, 13 fires scarred trees on two or more of the six plots with an average interval between multiplot fires of 21 years (Table 1). Such fires probably would have lightly burned sizeable portions of this small pine forest. Before fire control the study tree at plot 6, which was particularly sensitive to fire, was scarred at least 18 times with an average interval of 15 years. A large proportion of the short fire intervals (10 years or less) occurred early in the record: eight before 1809, two after 1809. A decline in lightning frequency would help to explain this shift. But if the Indians started more fires than the Spanish or Mexicans, another cause could be the destruction of the Indian culture near the peak soon after 1800.

We emphasize that this sort of fire scar record is a conservative estimate of the fires in the study area. Kilgore and Taylor (1979) also stressed the difficulties in comparing fire frequencies when different sampling intensities and different habitat types were involved. Nevertheless, the 21-year average interval between multiplot fires in the J. S. Pk. pine forest before fire control may be longer than intervals in the most similar California reports: 10 years for *P. ponderosa* forest, 12 years for *P. jeffreyi* forest (San Bernardino Mts.: McBride and Laven, 1976); 6–9 years for *P. ponderosa* forest, 8–17 years for mixed conifer forest (southern Sierra Nevada: Kilgore and Taylor, 1979).

Qualitative review of the fire scar record and evidence of fire recorded higher in the boles of the pines suggest the Marble-Cone fire was the most intensive burn to occur within the J. S. Pk. pine forest during the past 3 centuries. Limb breakage from a wet snowstorm in January, 1974 (Morrison, 1976) added greatly to fuel accumulation at low and middle elevations in the Santa Lucia mountains but did not damage vegetation above 1000 m on J. S. Pk. Two consecutive drought seasons, reducing precipitation below half of normal, preceded the Marble-Cone fire and also increased fire damage. However, the absence of fire over the previous 76 years was the single most important factor contributing to the intensity of the Marble-Cone fire within the J. S. Pk. pine forest.

*Pre-fire vegetation.* On the south side of J. S. Pk., *P. lambertiana* is restricted to colonies on rock outcrops above 1500 m (Fig. 1). Slopes within these rock outcrops exceed 100 percent, vegetation is sparse, litter does not accumulate, and the colonies do not burn readily. They had opportunity to burn when the Indians fire ran directly up to them and again when the Marble-Cone fire ran around them (Fig. 1).

The outcrop plot 13, which did not burn in either fire, had tree and shrub strata cover of 35 percent. In order of increasing importance, the cover was composed of *P. coulteri, P. lambertiana, Arctostaphylos glandulosa,* and *Quercus chrysolepis*. Young pines were rare. Species richness is higher on south-slope outcrops than in other J. S. Pk. communities (Griffin, 1975b; Talley, 1976). The herb and subshrub strata included *Arabis breweri, Castilleja foliosa, Cheilanthes covillei, Dudleya cymosa, Galium angustifolium, G. clementis, Hieracium argutum* var. *parishii, Lotus argophyllus* var. *fremontii, Lupinus abramsii, L. hirsutissimus, Penstemon corymbosus, Polystichum munitum, Stipa coronata,* and *Yucca whipplei*.

To the north of the ridgeline, *P. lambertiana–P. coulteri* forest extends down to 1200 m in some situations (Fig. 1). North-slope outcrops are common near plot 2. Enough moss and litter accumulate on parts of these outcrops to carry a light, spotty fire. Vegetation cover does not exceed 25 percent and is dominated by slow growing *Quercus chrysolepis* and scattered *Arctostaphylos glandulosa*. Bushy *P. lam-*

TABLE 2. BASAL AREA AND DENSITY OF *Pinus lambertiana, P. coulteri,* AND *Quercus chrysolepis* WITHIN THE JUNIPERO SERRA PEAK FOREST BEFORE AND AFTER THE MARBLE-CONE FIRE. *Calocedrus decurrens* is also present at plot 3 with 4.7 $m^2$/ha basal area, 115 stems/ha density (1-76) and 1.4 $m^2$/ha basal area, 86 stems/ha density (7-78).

| Plot | Basal area ($m^2$/ha) | | | | | | Density (stems/ha) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *P. lam.* | | *P. cou.* | | *Q. chr.* | | *P. lam.* | | *P. cou.* | | *Q. chr.* | |
| no. | 1-76 | 7-78 | 1-76 | 7-78 | 1-76 | 7-78 | 1-76 | 7-78 | 1-76 | 7-78 | 1-76 | 7-78 |
| | | | | | SUMMIT FOREST | | | | | | | |
| 12 | 16.2 | 6.8 | 47.8 | 24.2 | 0.4 | 0 | 717 | 72 | 516 | 229 | 57 | 0 |
| 8 | 85.2 | 41.9 | 1.4 | 1.3 | 0 | 0 | 976 | 158 | 43 | 14 | 0 | 0 |
| 5 | 57.2 | 56.4 | 6.6 | 6.8 | 2.8 | 1.9 | 244 | 215 | 43 | 43 | 115 | 57 |
| 4 | 30.8 | 4.4 | 19.3 | 17.3 | 4.9 | 0 | 1004 | 43 | 215 | 129 | 502 | 0 |
| 9 | 59.0 | 4.0 | 4.3 | 0 | 12.8 | 0 | 560 | 14 | 43 | 0 | 660 | 0 |
| Ave. | 49.7 | 22.7 | 15.9 | 9.9 | 4.2 | 0.4 | 700 | 100 | 172 | 83 | 267 | 11 |
| | | | | | SLOPE FOREST | | | | | | | |
| 11 | 42.8 | 21.8 | 0 | 0 | 32.4 | 18.4 | 129 | 14 | 0 | 0 | 731 | 229 |
| 1 | 9.5 | 8.6 | 3.1 | 3.2 | 16.6 | 3.4 | 187 | 129 | 28 | 28 | 1937 | 488 |
| 10 | 71.8 | 44.3 | 0 | 0 | 5.0 | 1.7 | 158 | 86 | 0 | 0 | 187 | 14 |
| 6 | 53.8 | 50.2 | 0 | 0 | 8.6 | 7.0 | 287 | 201 | 0 | 0 | 316 | 143 |
| 3 | 21.5 | 19.0 | 0 | 0 | 24.5 | 22.0 | 144 | 100 | 0 | 0 | 631 | 430 |
| Ave. | 39.9 | 28.8 | 0.6 | 0.6 | 17.4 | 10.5 | 181 | 106 | 6 | 6 | 760 | 261 |

*bertiana* and *P. coulteri* account for only about 5 percent cover. Herb species largely restricted to north slope outcrops included *Allium campanulatum, Erigeron petrophyllus, Lomatium macrophyllum, Holodiscus microphyllus,* and *Stipa* (*latiglumis*?). *Galium clementis, Heuchera micrantha* var. *pacifica,* and *Polystichum munitum* grow on north slope outcrops and other rocky slopes within canyons.

We separated the non-outcrop pine forest on the north side into two topographic units—"summit" and "slope" forests. The summit forest was generally above 1650 m elevation with moderate slopes; plots averaged 1700 m and 42 percent slope. The slope forest had more broken topography, with plots averaging 1590 m and 57 percent slope, becoming steeper with decreasing elevation. Tree cover on summit plots was: *P. lambertiana* 52 percent, *P. coulteri* 12 percent, and *Q. chrysolepis* 16 percent. Cover data for slope plots were: *P. lambertiana* 25 percent, *P. coulteri* 1 percent, and *Q. chrysolepis* 49 percent. *Pinus lambertiana* accounted for about two-thirds of total basal area on both summit and slope forests (Table 2), but *P. lambertiana* density at slope plots was only 40 percent that of summit plots due to lower establishment on slopes after the 1901 fire. *Pinus coulteri* accounted for 23 percent of the total basal area and 15 percent of tree density at summit plots. On slope plots *P. coulteri* declined, and only a few trees grew near chaparral ecotones. *Quercus chrysolepis* increased from 6 percent basal area and 23 percent density at summit plots to 30 percent basal area and 73 percent density on slope plots (Table 2). In effect the nearly pure pine stands on the summit grade into pine-oak stands on steeper terrain. Lower slope and canyon bottom forests have some dominant *Calocedrus decurrens* trees (Table 2, plot 3); small *Calocedrus* trees were rare in the summit forest.

The only shrub common within the pre-fire summit forest was *Rhamnus californica* (Table 3). Herbs were too infrequent in the dense pine needle duff on the summit to appear in the stand survey but included *Viola purpurea, Mimulus subsecundus, Silene lemmonii,* and one small population of the rare disjunct *Cycladenia humilus* var. *venusta*.

In the slope forest, shrubs were also unimportant. A few colonies of *Arctostaphylos glandulosa* grew along with uncommon individuals of *Rhamnus* and *Ribes*. Herbs were more diverse and included *Galium clementis, Carex multicaulis, Gayophytum heterozygum,* and *Pyrola picta* ssp. *aphylla*. *Lupinus cervinus* grew in small groups under semi-open stands dominated by large *P. lambertiana* trees (Table 3).

*Fire behavior.* The Marble-Cone fire crowned through portions of the summit forest (Fig. 1). None of the plots happened to be in areas where all the aboveground vegetation was killed, but only a few stems survived in plot 9 (Table 2). Stands consumed by the crown fire had dense understories that helped carry the crown fire. The origin of these pine thickets was related to old wind-throw damage. A few years after the 1901 fire a severe southwest wind felled patches of dominant *P. lambertiana* trees, and these openings regenerated densely without any subsequent thinning by fire. The upper summit, above the wind-throw zone, had a more open understory and did not generate a crown fire. Instead a strong surface fire swept the region killing 85 percent of the pine and all oak stems (Table 2, plots 8, 12). The least vegetation damage within the summit forest occurred near plot 5, the site of the 1959 lightning fire, where basal area and density reductions were minor for the pines (Table 2).

When the fire burned downhill over the steep north slope terrain below 1650 m elevation, it changed from a crown-type to surface fire. Along the upper margin of the slope forest about half the pine and two-thirds of the oak cover were killed (Table 2, plots 10, 11). Heat generated by this surface fire generally decreased as the fire burned deeper into the pine-oak stands (Table 2, plots 1, 6) but was still sufficient to kill nearly all oaks that had sprouted after the 1901 fire. Most saplings and some large specimens of *P. lambertiana* were also killed although mortality of intermediate sized pines was nil.

Significant areas in canyon bottoms remained unburned due to the presence of local fire barriers such as steep slopes with bare mineral

TABLE 3. PRE-FIRE (1976) AND POST-FIRE (1978) CONSTANCY PERCENT/MODAL COVER-ABUNDANCE VALUES (Mueller-Dombois and Ellenberg, 1974) FOR SPECIES IN THE SHRUB AND HERB STRATA ON THE JUNIPERO SERRA PEAK STUDY PLOTS.

| | Slope forest | | Summit forest | |
|---|---|---|---|---|
| Species | 1976 | 1978 | 1976 | 1978 |
| Trees and shrubs from sprouts | | | | |
| *Quercus chrysolepis* | 20/+ | 100/1 | 60/+ | 100/+ |
| *Rhamnus californica* | | | 80/+ | 80/+ |
| *Ribes roezlii* | | | 20/+ | 60/+ |
| *Arctostaphylos glandulosa* | 20/1 | 20/+ | | |
| Trees from 1977 seeds | | | | |
| *Pinus* spp. | | 100/+ | | 100/+ |
| *Quercus chrysolepis* | | 100/+ | | 100/+ |
| *Calocedrus decurrens* | | 40/+ | | |
| Shrubs and herbs largely from dormant seeds | | | | |
| *Ceanothus integerrimus* | | 100/+ | | 100/+ |
| *Mentzelia pinetorum* | | 60/+ | | 80/+ |
| *Hulsea heterochroma* | | 60/+ | | 100/+ |
| *Arctostaphylos glandulosa* | | 40/+ | | 60/+ |
| *Lupinus cervinus* | 40/+ | 100/+ | | 20/+ |
| *Claytonia spathulata* | | 40/+ | | |
| *Emmenenthe penduliflora* | | 40/+ | | |
| *Gayophytum heterozygum* | | 20/+ | | 100/+ |
| *Claytonia perfoliata & rubra?* | | 20/+ | | 80/+ |
| *Phacelia brachyloba* | | 20/+ | | 80/+ |
| *Lupinus abramsii* | | 20/+ | | 60/+ |
| *Ribes roezlii* | | 20/+ | | 40/+ |
| *Mimulus subsecundus* | | | | 40/+ |

soil or rock outcrops. No single fire seems capable of burning the entire area within canyons. Fires in regions that do burn may not kill mature trees depending upon elapsed time since the last fire or local fuel accumulations. Rugged terrain deep within canyons did not permit the fire to burn along a uniform front. Rather, the fire was dissected into numerous small surface fires, only a few of which reached the bottoms of canyons. Hence, portions of adjacent slopes that could carry fire did not burn.

*Post-fire vegetation.* Pine regeneration has been abundant. Only a few pine seedlings grew near plot 5 before the fire. Now hundreds of seedlings grow on all plots. We don't know if the seeds producing 1978 seedlings all came from normally maturing cones on trees surviving the fire or if the somewhat immature cones forced open by the crown fire contributed viable seeds. In the case of *P. coulteri,* some pre-1977 seeds stored in partially closed cones might have been involved.

On four regeneration plots in the crown fire area on the summit the mortality of 1978 seedlings has been minor. The average density of two-year old seedlings on the plots in 1979 was $0.3/m^2$ for *P. coulteri* and $0.1/m^2$ for *P. lambertiana*. All these seedlings were healthy, but the *P. coulteri* seedlings were several times taller. The largest *P. coulteri* seedlings reached 50 cm in height by August, 1979. Because *P. coulteri* represented only some 20 percent of the basal area before the fire, the three-fold density advantage of the vigorous *P. coulteri* seedlings suggests a shift toward *P. coulteri* dominance in the new summit forest, at least in the early stages.

There were no *P. coulteri* seedlings in the regeneration plot on the slope that sustained only a surface fire (Fig. 1). In both 1978 and 1979, many *P. lambertiana* seedlings started in the deep shade here, but survival was poor on this already heavily stocked plot. A few *Calocedrus* seedlings were present here and at the other slope plots (Table 3). Only one *Calocedrus* seedling was found on the summit regeneration plots in 1979.

Sprouting species responded to the fire as expected (Table 3). Burned *Q. chrysolepis* stems on all plots sprouted vigorously. On slope plots, 1977 acorns also germinated to expand the number of oaks present. The few pre-fire *Arctostaphylos glandulosa* shrubs in the slope forest sprouted, but this manzanita also came up from dormant seeds in many spots. Both *Ribes roezlii* and *Rhamnus californica* shrubs sprouted. *Ribes* seedlings appeared in some new areas; no *Rhamnus* seedlings were seen.

An important response from dormant seeds has been the impressive start of *Ceanothus integerrimus* seedlings. Although this shrub was common in chaparral around the forest, no *C. integerrimus* shrubs grew within the forest in 1976. Now *C. integerrimus* seedlings are common throughout the summit forest. *Ceanothus* seedling density on four summit regeneration plots averaged $13/m^2$ in 1978 with less than 5 percent cover; in 1979 density declined to $8/m^2$, but cover increased to more than 10 percent. These *Ceanothus* seedlings along with the lesser number of manzanita seedlings and sprouts will form a significant shrub understory. When the new pine thickets start to shade out the shrubs in several decades, a severe fuel hazard will develop again. Repeated light fires are needed to remove the dying shrubs and to thin the pine saplings without killing the remaining mature pines.

The fire triggered a dramatic increase in herbs (Table 3). Vigorous plants of the perennial *Lupinus cervinus* were seen in all old localities, and seedlings expanded old stands and started new ones. Before the fire the perennial *Lupinus abramsii* grew only on south-slope outcrops. Now it is widely scattered in the summit and slope forests. Other perennials such as *Penstemon centranthifolius* that were rare in the forest are now locally common. The most restricted species on J. S. Pk. is *Eriogonum spergulinum* var. *reddingianum*. Howitt and Howell (1964) listed this Sierra Nevada and north Coast Range disjunct annual on the summit, but we could not find it prior to the fire. However, in 1978 we found a colony covering about 50 $m^2$. The U.S. Forest Service aerially seeded *Lolium multiflorum* over much of the burn, but this grass was not sown over the north side of J. S. Pk. Minor amounts of seed drifted into the summit forest, but the resulting grass was negligible in terms of competition with pine seedlings and native herbs in 1978 and 1979 (the grass was a serious competitor in other portions of the burn). The major response from fire-induced annuals during the second year after the burn was a dramatic increase in *Gayophytum heterozygum* throughout the forest.

Unless periodic fire returns to the J. S. Pk. pine forest, areas burned in crown or surface fires in 1977 will produce *P. coulteri* and *P. lambertiana* thickets. Needles and dead limbs from the developing pine thickets will combine with the large number of overstory snags and the dying understory *Ceanothus* shrubs to produce a serious conflagration potential within 20–30 years. Such a conflagration would deplete further the remaining old growth pines and encourage the sprouting species. Should a 50-year or greater interval between fires be repeated several more times, the *P. lambertiana* forest on the north slope of J. S. Pk. above 1600 m, which makes up 40 percent of the forest today, may well be replaced by chaparral and scrubby oak stands. If pines remain on the summit, *P. coulteri* is the more likely to survive because of its more aggressive seedling growth. *Pinus lambertiana* may remain in the low-fire-hazard, north-slope canyons regardless of fire frequency. On the south slope of the mountain, pines apparently have been restricted to unburnable rock outcrops within the chaparral for centuries.

## Acknowledgments

Portions of the field work were supported by the Pacific Southwest Forest and Range Experiment Station, Berkeley; and Lick Observatory, University of California, Santa Cruz. We thank Robert Breazeale and his staff on the Monterey Ranger District, King City, for their interest and many types of practical help.

## Literature Cited

Arno, S. F. and K. M. Sneck. 1977. A method for determining fire history in coniferous forests of the mountain west. USDA Forest Service Gen. Tech. Report INT-42.

Biswell, H. H. 1963. Research in wildland fire ecology of California. Proc. Second Annual Tall Timbers Fire Ecology Conf., p. 63–97.

———. 1967. Forest fires in perspective. Proc. Calif. Tall Timbers Fire Ecology Conf. 7:43–63.

Burcham, L. T. 1959. Planned burning as a management practice for California wild lands. Calif. Div. Forestry, Sacramento.

Cooper, C. F. 1960. Changes in vegetation, structure, and growth of southwestern pine forests since white settlement. Ecol. Monogr. 30:129–164.

———. 1961. Pattern in ponderosa pine forests. Ecology 42:483–499.

GORDON, B. L. 1977. Monterey Bay Area: natural history and cultural imprints, ed. 2. Boxwood Press, Pacific Grove, CA.

GRIFFIN, J. R. 1975a. Plants of the highest Santa Lucia and Diablo Range Peaks, California. USDA Forest Service Res. Paper PSW-110.

———. 1975b. Ecological survey of Junipero Serra Peak candidate Botanical Area, Monterey District, Los Padres National Forest. Consultant report (P.O. 1180-PSW-75), Pacific Southwest Forest and Range Exp. Sta., Berkeley, CA.

———. 1978. The Marble-Cone fire ten months later. Fremontia 6:8–14.

——— and W. B. CRITCHFIELD. 1972. The distribution of forest trees in California. USDA Forest Service Res. Paper PSW-82.

HOWITT, B. F. and J. T. HOWELL. 1964. The vascular plants of Monterey County, California. Wasmann J. Biol. 22:1–184.

KILGORE, B. M. and D. TAYLOR. 1979. Fire history of a sequoia-mixed conifer forest. Ecology 60:129–142.

KROEBER, A. L. 1925. Handbook of the Indians of California. Smithsonian Inst. Bur. Ethnology Bull. 78.

LICK OBSERVATORY. 1977. Draft environmental impact report on the proposed dark sky optical observatory at Junipero Serra Peak. Univ. California, Santa Cruz.

LOS ANGELES HERALD. 8 Oct. 1906. 34(7):1.

MCBRIDE, J. R. and R. D. LAVEN. 1976. Scars as an indicator of fire frequency in the San Bernardino Mountains, California. J. For. 74:439–442.

MORRISON, G. A. 1976. Environmental analysis report, Monterey District prescribed burn program, 1976, Los Padres National Forest, King City, CA.

MUELLER-DOMBOIS, D. and H. ELLENBERG. 1974. Aims and methods of vegetation ecology. John Wiley and Sons, New York.

PLUMMER, F. C. and M. G. GOWSELL. 1905. Forest conditions in the Monterey Forest Reserve, California. Unpubl. report on file, Los Padres Natl. Forest, Goleta, CA.

STERLING, E. A. 1904. Fire notes on the Coast Ranges of Monterey County: timber and fires. Unpubl. report on file, Forestry Library, Univ. California, Berkeley.

TALLEY, S. N. 1976. The role of fire within montane pine forest, Junipero Serra Peak, Los Padres National Forest, California. Consultant report (Sec. I, No. 000171), Lick Observatory, Univ. California, Santa Cruz.

U.S. FOREST SERVICE. undated. Fire maps for the Monterey District, Los Padres National Forest, 1911–1969. Unpubl. report on file, Los Padres Natl. Forest, Goleta, CA.

VOGL, R. J. and B. C. MILLER. 1968. The vegetational composition of the south slope of Mt. Pinos, California. Madroño 19:225–234.

WAGENER, W. W. 1961. Past fire incidence in Sierra Nevada forests. J. For. 51:739–748.

(Received 17 Sep 1979; revision received 13 Dec 1979; accepted 30 Dec 1979.)